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BUREAU OF ENTOMOLOGY AND PLANT QUARANTINE

Project	Date	Author

SUBJECT—

TITLE

THE BLACK-HEADED BUDWORM SURVEY

ON THE TONGASS NATIONAL FOREST, ALASKA

Season of 1952

By

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APPRAISAL SURVEY

Thayer Lake, Admiralty Island, Alaska

By G. L. Downing, Entomologist

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
ALASKA FOREST RESEARCH CENTER
Juneau, Alaska
March, 1957

WESTERN HEMLOCK DAMAGE CAUSED BY THE BLACK-HEADED BUDWORM

APPRAISAL SURVEY

Thayer Lake, Admiralty Island, Alaska

G. L. Downing

This report covers an appraisal survey of severe damage to mature western hemlock, Tsuga heterophylla (Raf.) Sarg.), caused by the black-headed budworm, Acleris variana Fern., at Thayer Lake, Admiralty Island, Alaska. The survey was conducted from August 6 to August 11, 1956, by G. L. Downing and D. E. Bright of the Alaska Forest Research Center.

From approximately 1947 (6) until, and including, 1955 (2) an outbreak of the black-headed budworm occurred over most of the hemlock-spruce coastal forests of Southeast Alaska. The black-headed budworm was responsible for the defoliation of western hemlock, mountain hemlock, Tsuga mertensiana (Bong.) Carr.), and Sitka spruce, Picea sitchensis (Bong. Carr.). Western hemlock was the preferred host.

During most of this same period an associated outbreak of the hemlock sawfly, Neodiprion Tsugae Midd., occurred on western hemlock at scattered locations in Southeast Alaska.

Defoliation resulting from the feeding of the black-headed budworm and/or the hemlock sawfly caused top-killing of hemlock in many areas (3) and complete killing of hemlock within some of these areas (8). Owing to the complexity of the outbreak pattern of both the black-headed budworm and the hemlock sawfly, it is difficult in some areas to definitely assign responsibility for damage to either of these insect species individually. At Thayer Lake, where this survey was conducted, most of the damage was caused by the black-headed budworm, with the hemlock sawfly playing a minor role.

Although the black-headed budworm was epidemic in Southeast Alaska from 1947 to 1955, as a general rule it did not occur in any one locality for more than two or three years. At Thayer Lake a heavy population existed in 1952, increased and caused severe defoliation in 1953, declined to a light population level in 1954 (6), and entirely disappeared from the scene by 1955.

Throughout the course of this epidemic there has been much speculation as to the actual amount of permanent damage that has resulted from the defoliation of the stands. Small-scale studies have provided some data on the damage to young-growth hemlock and spruce stands (7), but very little data have been available regarding the damage occurring within the old-growth hemlock-spruce stands. The data presented in this report were gathered in an area known to have suffered heavy defoliation resulting in severe damage to the stand. Further sampling is planned within mature stands of light, moderate, and heavy damage.

DESCRIPTION OF THE SURVEYED AREA

Most of the stands in the vicinity of Thayer Lake were heavily damaged in the recent outbreak. The area selected for the appraisal survey is 800 acres in size and slightly rectangular in shape. It is located on the west side of the lake and just to the south of the lake outlet. There is an elevational change from about 100 feet above sea level to 1200 feet above sea level. Most of the surveyed stand is on north to west-facing slopes.

SURVEY METHOD

Data were taken from a series of one-quarter-acre plots, spaced four chains apart on cruise lines that were run at approximately ten-chain intervals. The plots were located by hand compass and pacing. Altogether 105 of these quarter-acre plots were taken.

On each plot all damaged trees above 11.0" d.b.h. were tallied and the following information recorded: tree species, d.b.h. to the nearest 2-inch class, number of 16-foot logs, damage class, and crown class.

Four classes of damaged trees were recognized: (1) completely killed trees, (2) 3/4 top-killed trees, (3) 1/2 top-killed trees, and (4) 1/4 top-killed trees.

During the cruise four crown classes were tallied: dominant, codominant, intermediate, and suppressed. In compiling the data for this report it was found to be more reliable to group the crown classes into two groups: overstory, includes dominant and codominant; and understory, includes intermediate and suppressed.

On every third plot all of the trees above 11.0" d.b.h. were tallied, including both damaged and green trees. The same information was recorded on these plots as on the other one-quarter-acre plots. Every third plot serves as both a damage plot and a green-stand plot. Green-stand information was recorded on 36 plots.

Volumes were figured from Girard and Bruce (4) board foot volume tables. Several downed hemlock trees were checked to establish an average form class of 82. This is also considered to be the average form class for both Sitka spruce and western hemlock in Southeast Alaska (1).

Determination of cull was not attempted in this survey. The main reason for omitting this was the feeling that cull could not be accurately determined by a post-mortem of the insect-killed trees. It is known, however, that the total gross cull in the general area of the survey is about 34 percent for western hemlock and 15 percent for Sitka spruce.[1/] These figures have been applied to several of the volume totals in this

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1/ Obtained from recent data compiled by the Forest Survey, Alaska Forest Research Center, Juneau, Alaska.

report in order that the reader may be made aware of the differences in gross and net volume. Most of the figures ~~and the graph comparisons~~ in this report are based on gross volume.

All standard error figures in this report have been calculated at the 68 percent confidence level.

THE GREEN STAND BEFORE DAMAGE OCCURRED

Determination of the composition of the green stand before the epidemic occurred has been accomplished by combining the damaged tree data and green tree data that were collected on every third plot. It has been shown (5) that climax stands in Southeast Alaska, which include the type of stands involved in this survey, are static in character and making practically no growth. Because of this condition, no adjustment has been made in the green stand figures for any growth between the period prior to insect attack and the 1956 cruise.

Green stand data are for trees 11.0" d.b.h. and larger and were obtained from 36 one-quarter-acre plots.

STAND COMPOSITION

Western hemlock and Sitka spruce were the only tree species over 11.0" d.b.h. encountered. The following is a breakdown of the stand volume and number of trees per acre prior to the insect-caused damage.

	Bd. ft./acre	% of volume	No. trees per acre	% of total no. trees
Western hemlock	31,207	92.3	42.0	91.3
Sitka spruce	2,596	7.7	4.0	8.7
Total	33,803	100.0	46.0	100.0
Standard error	± 2,900		± 2.7	

The net volume for the stand, including both hemlock and spruce, was 22,803 board feet per acre.

All permanent top-killing and complete tree killing was confined to western hemlock. Since Sitka spruce sustained no permanent damage, the remainder of this report will deal entirely with the hemlock portion of the stand.

THE HEMLOCK STAND

The composition of the hemlock stand at the time of the insect outbreak was as follows:

	Overstory	Understory	Total	Standard error
Bd. ft./acre (gross)	29,651	1,556	31,207	± 2,908
Percent	95.0	5.0	100.0	
Trees/acre	31.7	10.3	42.0	± 2.7
Percent	75.4	24.6	100.0	
Average d.b.h., inches,			20.6	

DAMAGE

Although the survey was conducted approximately three years after permanent tree damage occurred, no difficulty was encountered in relating tree damage to budworm defoliation. All of the damaged trees exhibited the same relative degree of deterioration in the damaged portions of the tree crowns. At the time of the survey the damaged portions of the trees had lost all of their larger branches and twigs, and most of their twiglets. Basal examinations of many completely killed trees indicated the presence of a few secondary insect species, but in no case were these insect species considered primarily responsible for the death of the trees.

The damaged trees in the sample averaged 24.0 inches d.b.h.

VOLUME LOSS

Table 1 shows the distribution of black-headed budworm-caused damage on a gross board foot per acre basis, by damage classes.

Table 1.--Distribution of black-headed budworm-caused damage to western hemlock - Thayer Lake, Admiralty Island, Alaska

By gross board foot volume per acre within damage classes[1/]

	Complete kill	3/4[2/] top-kill	1/2 top-kill			1/4 top-kill			Total
			Damaged portion	Green portion	Sub-total	Damaged portion	Green portion	Sub-total	
Board feet/acre	5,835	2,841	1,469	2,729	4,198	852	3,408	4,260	17,134
Standard error	± 764	± 720			± 744			± 636	± 1,656
% of total damage	34.0	16.6			24.5			24.9	100.0
% of green stand	18.7	9.1	4.7			2.7			35.2
				8.7			10.9		19.6
					13.4			13.6	54.8

1/ Trees 11.0" d.b.h. and larger.
2/ 3/4 top-killed trees are considered as total volume losses.

Probably the most important thing brought out in this survey is the fact that completely killed trees do constitute a considerable proportion of the stand volume. This damage class accounts for 18.7 percent of the stand volume, followed by 3/4 top-killed trees with 9.1 percent. From a practical standpoint the 3/4 top-killed trees can be considered the same as a complete kill. Even if they survive they would not be considered as merchantable. In this regard there is reason to believe that many of the severely top-killed trees will become complete kills. During the course of the cruise a few of the completely killed trees were found to possess dead needles in the lower branches but none in the upper branches. This would indicate that these trees were top-killed by the black-headed budworm and then died as a result of progressive dying of the remaining green crown. All of the trees found in this condition appeared to have been initially top-killed throughout more than half of the crown length.

The actual damaged portion of the trees within all damage classes amounts to 35.2 percent of the stand volume, with the total volume in all of the damaged trees constituting 54.8 percent of the stand volume.

The gross volume in all classes of damaged trees is 17,134 board feet per acre. Deducting the green volume in the 1/2 and 1/4 top-killed trees leaves 10,996 board feet per acre. A 34 percent flat cull deduction from this figure leaves 7,258 board feet per acre as the net volume loss per acre. This should be compared to the estimated net green stand volume of 22,803 board feet per acre. It should be pointed out that the net volume figures are only estimates and based on a flat 34 percent cull figure developed from data covering a green stand. Information is lacking concerning the relationship of cull in the green stand and resultant black-headed budworm-caused damage. This information should be obtained through a joint study by an entomologist and a pathologist. Such a study will most likely have to await the development of a new black-headed budworm outbreak.

TREE LOSS

Table 2 shows the distribution of black-headed budworm-caused damage in number of trees per acre by damage classes.

Complete tree kills represented 13.1 percent of the stand, or 5.8 trees per acre. All classes of tree damage combined total 17.5 trees per acre, or 41.6 percent of the stand. Of the estimated 33,600 trees above 11.0" d.b.h. on the 800 acre surveyed area, approximately 14,000 were damaged by the budworm and of this total 4,640 were completely killed.

The figures in Table 3 show that the damage resulting from black-headed budworm defoliation occurred, by tree crown position, in approximately the same proportion as the trees naturally occurred in the stand. This is most easily seen by comparing the percentage figures for the green stand with those for the damaged stand. This means that, within the area of this survey, the black-headed budworm exhibited little or no feeding preference for either overstory or understory trees above 11.0" d.b.h.

Table 2.--Distribution of black-headed budworm-caused damage to western hemlock - Thayer Lake, Admiralty Island Alaska

By number of trees per acre within damage classes[1/]

	Complete kill	3/4 top-kill	1/2 top-kill	1/4 top-kill	Total
Trees/acre	5.8	1.9	4.0	5.8	17.5
Standard error	±0.7	±0.3	±0.5	±0.5	±1.2
% of total damage	32.9	11.1	22.9	33.1	100.0
% of green stand	13.1	4.6	9.5	13.8	41.6

1/ Trees 11.0" d.b.h. and larger

Table 3.--Relationship of budworm damage to hemlock crown position, Thayer Lake, Admiralty Island, Alaska, 1956

Board foot volume per acre	Overstory	Understory	Total	Standard error
Green stand	29,651	1,556	31,207	± 2,908
Percent	95.0	5.0	100.0	
Budworm damage	16,078	1,056	17,134	± 1,656
Percent	93.8	6.2	100.0	
Number of trees per acre				
Green stand	31.7	10.3	42.0	± 2.7
Percent	75.5	24.5	100.0	
Budworm damage	13.1	4.4	17.5	± 1.2
Percent	74.8	25.2	100.0	

DISCUSSION

It can be seen from the data presented in this report that the black-headed budworm, under favorable conditions, is capable of inflicting severe permanent damage upon a mature hemlock stand. Severe damage represents only a small percentage of the total damage that resulted from the budworm outbreak. Mapping of budworm and sawfly-caused damage is incomplete at present; however, severe damage will be but a few thousand acres out of a total damage acreage that is expected to exceed 100,000 acres.

Although the net volume loss has been given as 7,258 board feet per acre, it should be pointed out that this figure represents only the direct net loss due to budworm-caused damage. The green portion of the one-quarter top-killed trees and one-half top-killed trees may in time prove to be indirect losses. The progress of these trees will be followed.

Little, if any, indirect loss can be attributed to lowered increment because the climax stands involved have reached a point where growth is almost nil.

REFERENCES CITED

(1) Andersen, H. E. Girard form class comparisons for three major species in Southeast Alaska. Alaska Forest Research Center, Tech. Note No. 26, Juneau, Alaska. May 1955.

(2) Downing, G. L. Forest insect conditions in Alaska, 1956. Alaska Forest Research Center, Juneau, Alaska. Mimeo., December 1956.

(3) _____ Forest insect aerial survey, Southeastern Alaska, July-October, 1956. Alaska Forest Research Center, Juneau, Alaska. Mimeo., Dec. 1956.

(4) Girard, J. W. and D. Bruce. Tables for estimating board foot volume of trees in 16-foot logs. Mason, Bruce, and Girard, Portland, Oregon.

(5) Godman, R. M. A classification of the climax forests of Southeastern Alaska. Jour. Forestry 50 (6), June 1952.

(6) McCambridge, W. F. The black-headed budworm survey on the Tongass National Forest, Alaska, season of 1954. Alaska Forest Research Center, Juneau, Alaska. Mimeo., Nov. 1954.

(7) _____ Effects of black-headed budworm feeding on second-growth western hemlock and Sitka spruce. Paper presented at the annual meeting, SAF, Portland, Oregon, Oct. 1955.

(8) _____ The black-headed budworm survey on the Tongass National Forest, Alaska, Season of 1955. Alaska Forest Research Center, Juneau, Alaska. Mimeo., Nov. 1955.

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THE BLACK-HEADED BUDWORM SURVEY ON THE TONGASS NATIONAL FOREST, ALASKA

Season of 1952

By

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November 1, 1952

C O N T E N T S

The Black-headed Budworm Survey

on the Tongass National Forest, Alaska

1952

SUMMARY

An annual survey program for evaluating forest insect conditions in Alaska was initiated in 1952. This initial survey was directed very largely against the black-headed budworm on the Tongass National Forest.

The black-headed budworm epidemic on the Tongass National Forest extends over approximately 11,640,000 acres of forest land. Western hemlock (Tsuga heterophylla) is most seriously defoliated but some feeding occurs on Sitka spruce and mountain hemlock. Heavy to very heavy defoliation of western hemlock extends from the Portland Canal to the northwest shore of Kupreanof Island - and area of 8,040,000 acres. The tops of many hemlocks have been killed throughout this area as a consequence of repeated budworm feeding, but no general tree killing has occurred to date. Light to moderate defoliation is believed to extend over an additional 3,600,000 acres between Frederick Sound and Berners Bay.

Egg counts made during September and early October indicate the infestation in 1953 will be light in the present areas of heavy defoliation. In the light to moderate areas, defoliation in 1953 is expected to continue. No control of the budworm epidemic is recommended. The history of black-headed budworm epidemics in the Pacific Northwest and in Canada is one of build-up, scattered top killing of hemlock, and decline before general tree killing results. It appears that this history is repeating itself on the southern half of the Tongass. Budworm moths were very prominent in all areas sampled, but high egg counts were recorded only in areas of light to moderate defoliation. Parasitic wasps emerged in relative abundance from budworm pupae collected in the vicinity of Petersburg, Ketchikan and Hollis. However, this relative abundance of wasps did not substantially reduce the magnitude of moth flights in these areas.

The hemlock sawfly in conjunction with the budworm is causing considerable defoliation in the vicinity of Polk Inlet and McKenzie Inlet on Prince of Wales Island. The added feeding by the sawfly, while potentially serious, has not reached alarming proportions. Much lighter sawfly populations were found from the Admiralty Lakes region to Ketchikan.

INTRODUCTION

The rapidly expanding utilization of federally owned forested lands in Alaska has brought forth the need for more intensified management, research and protection. Recognizing the fact that insect surveys are an essential requirement of forest protection, the Congress of the United States approved a request for funds to be used for forest insect surveys in Alaska during the fiscal year of 1953.

During previous years the U. S. Forest Service, Bureau of Land Management, and various individuals have reported on forest insect conditions to the Forest Insect Laboratory at Portland, Oregon. R. L. Furniss, Entomologist-in-Charge, has made irregular visits of short duration to check on the more urgent problems.

When money for surveys in Alaska became available, the author of this report was given the survey assignment. The areas of widespread defoliation by the black-headed budworm Acleris variana, Fern. recently reported by the Forest Service in proposed pulp allotments on the Tongass National Forest were given immediate attention.

The survey of the black-headed budworm epidemic was completed through the excellent cooperation of all Forest Service personnel contacted in Region 10. Members of the Alaska Forest Research Center provided valuable field notes and study plots. Supplemental survey information was supplied by the U. S. Geological Survey and Ellis Airline Company.

PAST OUTBREAKS

Outbreaks of the black-headed budworm have appeared at irregular intervals throughout the hemlock forests of southeastern Alaska for many years. A. J. Jaenicke, Timber Management staff, Region 6, investigated widespread defoliation on the Tongass National Forest in 1919. Jaenicke found the defoliation was caused by both the black-headed budworm and the hemlock sawfly. B. F. Heintzlemen, Regional Forester, Region 10 has observed black-headed budworm infestations scattered throughout the Tongass for many years. Old snag tops and patch killing adjacent to the Portland Canal, the Peril Straight, and other locations are undoubtedly evidence of such outbreaks.

PRESENT OUTBREAK

History: In 1948, a small infestation was seen at the mouth of Anan Creek, on the mainland southeast of Wrangell Island. It is believed that the current outbreak was beginning about this time. By 1950, the infestation was becoming more widespread and personnel of the Alaska Forest Research Center made collections of the budworm in Twelve Mile Arm on Prince of Wales Island. During late summer of 1951, Ivan H. Jones, Southern Division, reported considerable defoliation was noticeable from El Capitan Pass to Chomley Sound on Prince of Wales Island and in the vicinity of Gedney Pass on the northern end of Revillagigedo Island. That same year, H. E. Anderson, Alaska Forest Research Center, reported extensive budworm defoliation extended from Petersburg to the southeastern end of Etolin Island and east to the mainland. From these accounts and observations made this year, it is believed that by the end of 1951 the black-headed budworm epidemic extended from the Portland Canal northwestward to Cape Bendel on the north shore of Kupreanof Island. Some scattered light infestations probably existed as far north as the Admiralty Lakes region on Admiralty Island.

Survey Results - 1952: The black-headed budworm survey was carried out during the period from August 26 to October 14. During that period complete aerial coverage was made of the southern half of the Tongass National Forest. Samples and observations were taken at 26 localities.

The black-headed budworm epidemic on the Tongass National Forest is believed to extend over approximately 11,640,000 gross acres of forest land (See accompanying map). Heavy and very heavy defoliation of western hemlock, where some top killing occurs, is found throughout 8,040,000 acres. These degrees of defoliation extend from British Columbia south of the Portland Canal, to the northwest shores of Kupreanof Island. Predominantly light and moderate defoliation is believed to extend throughout 3,600,000 acres situated between Frederick Sound and Berners Bay. A few small infestations of moderate to heavy defoliation were found within this area in the vicinity of the Admiralty Lakes. Similar degrees of defoliation probably extend southward on Admiralty Island. The various degrees of defoliation are defined on page 7 and 8.

Moderate budworm defoliation on young Sitka spruce (Picea sitchensis) trees was observed at Petersburg and Juneau. The larger spruce remain relatively free from attack, and no widespread defoliation is expected in 1953.

Very heavy moth flights were observed at Ketchikan, Hollis, Wrangell and Petersburg, and were reported very heavy at Juneau, Camp Sha-Heen (Admiralty Lakes), Chatham Straight and Berners Bay. Pilots for Alaska Coastal Airline and Ellis Airline Company, stated that when flying between Juneau and Ketchikan at altitudes of about 2000 feet, "bugs" would often hit their windshields in such numbers as to impair visibility. Insect remains found on the windshields proved to be budworm moths. While mapping the extent of the budworm epidemic in the vicinity of the Rosseau Range on the mainland many moths hit the windshield while flying at 4,000 feet over glaciers and barren mountain tops. Personnel of the U. S. Geological Survey reported making a count of 65 moths per square foot on a snow field east of Juneau. They estimated the elevation at which the count was made at between 3500 and 4000 feet and that the count was a good representative sample.

There appears to have been no real difference in the magnitude of the moth flight reported over various localities. However, egg counts made near Petersburg, Wrangell, Ketchikan and Hollis--areas of heavy to very heavy defoliation--seem to be significantly lower than those egg counts made near Juneau, Admiralty Lakes and Turner Lake--areas of light to moderate defoliation. See Table I on following page for generalized summary of the egg count data.

Egg count data taken from areas of light to moderate defoliation show two strong tendencies: (1) For trees having the same crown class, eggs are most numerous in the upper crown and least numerous in the lower crown; (2) Egg deposits for any given crown position increase as crown height, expressed as crown class, increases. The feeding pattern in the older epidemic areas supports this conclusion.

Egg counts recorded from areas of heavy to very heavy defoliation are so light that no conclusions can be made other than to surmise that defoliation of western hemlock will be light in 1953. The egg counts recorded from areas of light to moderate defoliation indicate defoliation will continue in 1953 at about the same intensity as occurred in 1952. The repeated budworm feeding should cause more noticeable browning of western hemlock stands, and some light scattered top killing can be expected.

TABLE 1. GENERALIZED SUMMARY OF EGG COUNT DATA

Data from twigs on suppressed trees and open grown reproduction

	Lower Crown				Middle Crown				Upper Crown			
	No. of twigs in sample	Inches of twig branch-lets	No. of eggs	Eggs per inch of twig branch-lets	No. of twigs in sample	Inches of twig branch-lets	No. of eggs	Eggs per inch of twig branch-let	No. of twigs in sample	Inches of twig branch-lets	No. of eggs	Eggs per inch of twig branch-let
Areas of heavy and very heavy defoliation	55	2448	49	.02	52	2305	61	.03	31	1280	26	.02
Areas of light to moderate defoliation	56	2793	110	.04	53	2171½	198	.09	53	1725½	570	.33
Data from twigs on intermediate trees												
Areas of heavy and very heavy defoliation	6	352	6	.02	2	154	0	0	2	42½	7	.16
Areas of light to moderate defoliation	15	796	75	.09	15	631	199	.32	15	453	197	.43

See Section on Method of Survey, page 6, for full discussion of column headings.
Insufficient samples were obtained from codominant and dominant trees to be tabulated.

METHOD OF SURVEY

Time: All aerial mapping was done during September. At this time hemlock stands having sustained moderate, heavy, and very heavy defoliation appeared dull brown in color. Ground observations were made between September 1 and October 13. Egg counts were made between September 22 and October 13; however, a few eggs were seen before this date.

Aerial Procedure: It would be nice to state that some hard and fast methods of procedure were used for the aerial mapping. Such was not the case. On clear days mapping was done at approximately 3500 feet by gridding the area--flying back and forth in more or less parallel flight lines. When the clouds were low, mapping was done at various altitudes below 3500 feet while flying with the ground contours. Combinations of gridding and contouring were used.

Best mapping condition existed when ceiling and visibility were unlimited. On such days, heavy and very heavy defoliation were visible from distances as great as 12 miles, provided the observer was looking away from the sun. The low angle of the sun, common to northern latitudes in the fall, caused excessive glare and heavy ground shadows which made it difficult to map when looking south. Most of the mapping on clear days was done while flying about 3500 feet above the ground. At this height it is difficult to detect moderate infestations, but the advantage of being able to map large areas of heavier defoliation was desirable at this time. Much of the flying was done under overcast skies, often when clouds covered the higher peaks. Under these conditions, accompanying clouds close to the ground made mapping very difficult and costly. The necessity of flying low, up and back long valleys, consumed more time than was necessary to map the infestations. However, at such times, flying height was less than 1000 feet and moderate infestations could be detected.

All of the aerial mapping was done using an Aeronca sedan flying at 85 miles per hour. The infested areas were mapped in place on a base map with scale of 12 miles equal 1 inch.

Mapping the heavy and very heavy areas of defoliation extending over 8,040,000 acres of forest land required a total gross land and water coverage of approximately 11,000,000 acres. This aerial coverage was accomplished in 35 hours and 20 minutes of flying time; approximately 5200 acres covered per minute. The longest flight in any one day was 10 hours and 10 minutes; the average daily flight was 7 hours and 4 minutes.

Ground procedure: The location of ground sampling points was determined entirely by routes of scheduled Forest Service boat trips and

the availability of boat and motor transportation. The Forest Service was extremely helpful and cooperative in making such transportation available. As a result, samples were taken at 26 locations clustered near Hollis, Ketchikan, Wrangell, Petersburg, Admiralty Lakes and Juneau.

All egg counts were made on 10-inch twigs cut from western hemlock. One twig, always at the end of the branch, was cut when practical from each of three positions on the tree; namely, lower crown, middle crown and upper crown. No egg counts were recorded from the terminal shoot. The length of branchlets on the twig bearing normal needle growth or equivalent was then measured (called inches of twig branchlets in Table I).

The degree of defoliation on each twig and in the general area were recorded. For the most part, egg counts were made from twigs on suppressed and intermediate trees. It was felt that because of the length of time required to cut dominant and codominant trees, a few samples in those crown classes would not be as desirable as more samples from the lower crown classes. The few egg counts made from dominant and codominant trees are much higher than counts made from corresponding positions on suppressed and intermediate trees.

In a detailed analysis of the data to be written at a later date, an attempt will be made to determine if a significant difference exists between egg deposits on suppressed trees and on open grown reproduction.

Classification of Defoliation

The various degrees of defoliation of hemlock stands are defined as follows:

Very heavy defoliation - Most of the current year and older needle growth throughout the major portion of the crown have been devoured by the budworm. All crown classes are effected. Top killing, in some cases as much as 40 feet, is prevalent. From the air very heavily defoliated hemlock stands appear brown with a tinge of gray.

Heavy defoliation - The current year's needle growth and most of the older growth in the upper crown has been devoured. Top killing is common on the dominant and codominant trees but is usually confined to within 20 feet of the top. From the air heavily defoliated hemlock appears reddish-brown in color, with some green visible when seen from directly overhead.

Moderate defoliation - Most of the current year's needle growth has been removed from the upper crown. Usually some older foliage near the top of the tree is also devoured. The heavier side of moderate defoliation is visible from the air under good light and at low flying heights. Moderately defoliated hemlock stands are off-color green.

Light defoliation - The current year's needle growth in the upper crown has been partially devoured. No off-color is visible either from the ground or from the air.

THE BUDWORM AND ITS HABITS

Moths of the black-headed budworm are predominantly mottled gray with a wide variety of wing markings. The adult moth is approximately 3/8 inch long and 1/4 inch wide. They may be seen flying in great numbers during late August and all of September. The peak of moth flight occurred in Juneau about the third week in September, ten days to two weeks later than the flight at Ketchikan. Mr. R. F. Taylor, Alaska Forest Research Center, points out that hemlock growth begins about two weeks earlier in Ketchikan than in Juneau.

Moths exhibit various flight habits. During some stages of their lives they appear quiescent, flying weakly when the trees are shaken. On October 13, large number of moths were disturbed from mountain hemlock (Tsuga mertensiana.) They appeared almost unable to fly, fluttering weakly to branches below and to the ground. At other times moths have been observed flying strongly in very heavy rain and at high altitudes. Moths have been observed to alight on the water, pause a few minutes and take flight again.

Eggs of the budworm are laid singly on the underside of the needles during September. They are approximately one millimeter long, oval in shape, flattened on top, and yellow in color. Eggs hatch as the buds begin to open, usually in June.

The larvae when young are light green in color with black heads. When full grown the larvae are bright green in color, slightly over 1/2 inch in length, and the head is brown. The budworm prefers to feed in the tops of the largest trees. By stripping the foliage and bunching the needles together for chambers in which to pupate, the budworm is able to produce the characteristic brown appearance of defoliated trees.

The pupae are shiny brown toward the head and brownish green on the abdomen. They are usually found within the bunched needles. Healthy pupae wiggle vigorously when disturbed. Considerable numbers of ichneumonid wasps have emerged from budworm pupae collected at various points from Juneau to Ketchikan. Wasps have been observed flying in great numbers at Ward Lake near Ketchikan, Petersburg and at Hasselborg Lake. The identity of the wasps has not yet been made.

The black-headed budworm prefers to feed on western hemlock, but Sitka spruce and mountain hemlock are also defoliated. Heaviest defoliation of western hemlock occurs in good stands on the well-drained slopes. This defoliation causes a noticeable browning along the middle of the slope, above and below which the hemlock remains noticeably greener.

HEMLOCK SAWFLY

The hemlock sawfly, Neodiprion tsugae, Midd. is causing heavy defoliation in conjunction with the black-headed budworm at McKenzie Inlet and Polk Inlet on Prince of Wales Island. The presence of hemlock sawfly and black-headed budworm is a serious situation because of the feeding habits of the two insects. Sawfly larvae feed on the older foliage whereas the budworm larvae prefer the new needle growth. A few sawfly cocoons and adults were seen near Petersburg, Zarembo Island, Wilson Island Bay, Ketchikan, Hollis, Hasselborg Lake and Lake Alexander. Sawfly cocoons collected at Petersburg and Hollis produced a relatively high percentage of ichneumonid parasites.

RECOMMENDATIONS

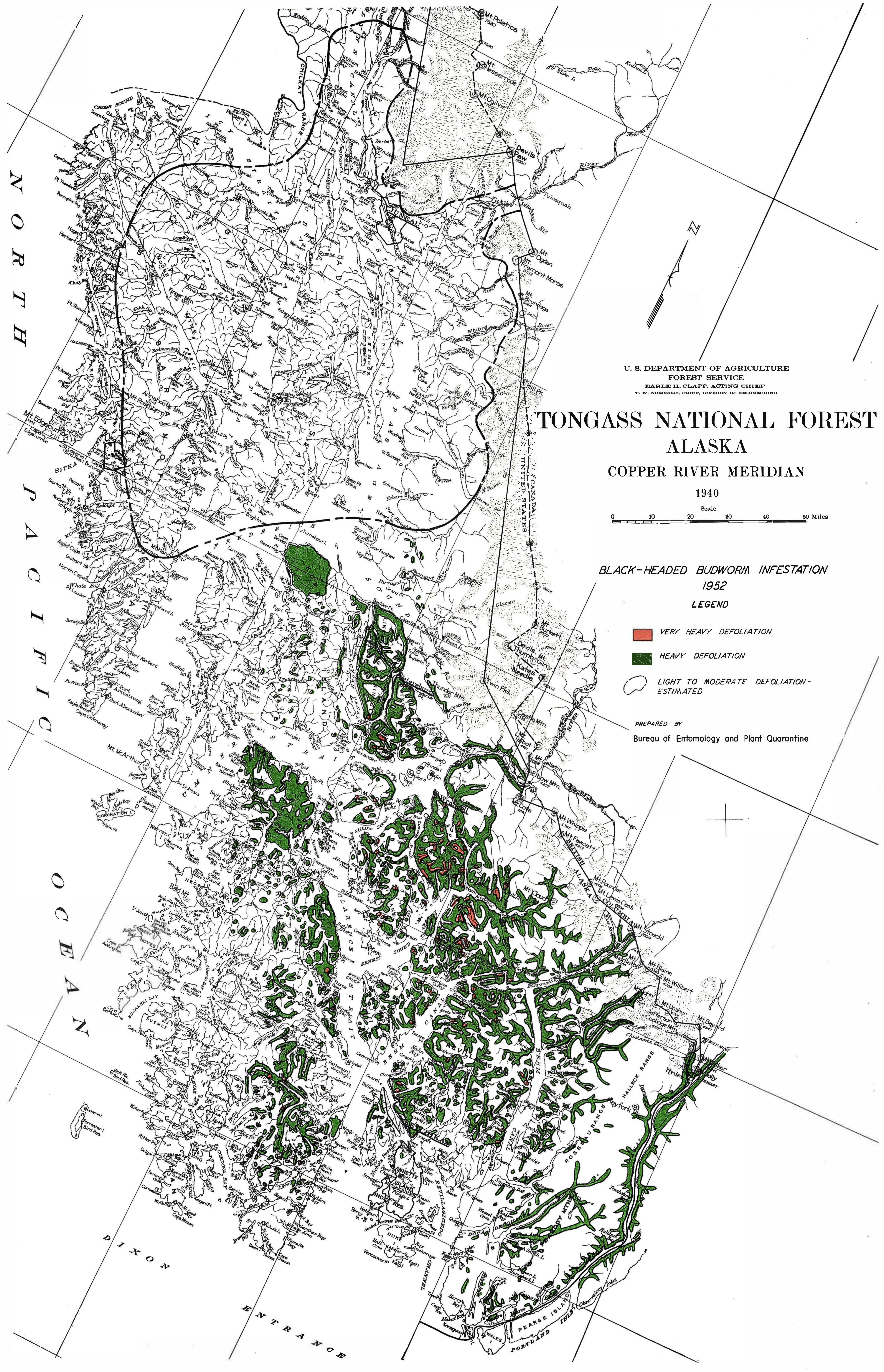
1. No direct control is recommended at this time. The low egg counts made in areas of previous heavy defoliation indicate light feeding in 1953. Continued defoliation in the present lightly infested areas is expected next year, but only scattered light top kill is foreseen.

2. Experimental work should be undertaken to determine the most effective insecticide, dosage and time of spray required to control the black-headed budworm.

3. Basic studies should be initiated to determine: (a) host-budworm relationships (b) natural control factors and their effects on the outbreak, and (c) evaluations of population densities.

4. Survey techniques to follow the course of the epidemic should be developed and improved.

5. A survey of the black-headed budworm infestation should be conducted in 1953.


U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
EARLE H. CLAPP, ACTING CHIEF
T. W. NORCROSS, CHIEF, DIVISION OF ENGINEERING
TONGASS NATIONAL FOREST
ALASKA
COPPER RIVER MERIDIAN
1940
Scale
0 10 20 30 40 50 Miles
BLACK-HEADED BUDWORM INFESTATION
1952
LEGEND
VERY HEAVY DEFOLIATION
HEAVY DEFOLIATION
LIGHT TO MODERATE DEFOLIATION - ESTIMATED
PREPARED BY
Bureau of Entomology and Plant Quarantine
NORTH PACIFIC OCEAN
DIXON ENTRANCE